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2018-09-17

Hybrid BWM-ELECTRE-based decision framework for effective offshore outsourcing adoption: a case study

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http://hdl.handle.net/10026.1/11513

10.1080/00207543.2018.1472406
International Journal of Production Research
Taylor & Francis

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Journal:	*International Journal of Production Research*
Manuscript ID	TPRS-2017-IJPR-2562.R1
Manuscript Type:	Special Issue Paper
Date Submitted by the Author:	n/a
Complete List of Authors:	Yadav, Gunjan; Sardar Vallabhbhai National Institute of Technology, Mechanical Engineering

	Mangla, Sachin; University of Plymouth, Plymouth Business School Luthra, Sunil; National Institute of Technology, Kurukshetra, Mechanical Engineering; Government Polytechnic, Jhajjar, Jakhar, Suresh; Indian Institute of Management, Operations Management Group
Keywords:	OUTSOURCING, DECISION SUPPORT SYSTEMS, MANUFACTURING SYSTEMS, PERFORMANCE MANAGEMENT, SUPPLY CHAIN MANAGEMENT, SUSTAINABILITY
Keywords (user):	Offshore outsourcing, Enablers, BWM, ELECTRE, Automotive Organisations

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Hybrid BWM-ELECTRE based decision framework for effective offshore outsourcing adoption: a case study

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Abstract

The present study seeks to develop a decision framework of enabler to help managers in offshore outsourcing adoption by focussing on the relevant enablers and their intensities. A hybrid Best Worst Method - ELimination and Choice Expressing REality approach is used to test the applicability of developed offshore outsourcing focused enabler's across four automotive business organisations in India and the adoption score of framework among case organisations is evaluated too. The intensity of offshore outsourcing focused enablers is analysed through Best worst method and the ranking of organisations and adoption index scores are computed through ELimination and Choice Expressing REality method. The developed framework possesses high adoption rate in offshore outsourcing initiatives across the case organisations. Findings of the study reveal that among the main enablers; managerial and strategic enabler holds the highest weight followed by technological enablers and organisational enablers. This study further presents the sensitivity analysis to check the robustness of developed framework by conducting experiments in different conditions. This research work will facilitate managers and professionals involved in practicing offshore outscoring initiatives and results in higher cost advantages on labor and raw material, increased economies of scale, and higher sustainable business development.

Keywords- Offshore outsourcing, Enablers, BWM, ELECTRE, MCDM, Automotive Organisations, Sustainable business development

Paper type- Research Paper

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Manuscript ID: First revision for manuscript TPRS-2017-IJPR-2562

Title of the paper: Hybrid BWM-ELECTRE based decision framework for effective offshore outsourcing adoption: a case study.

Respected Editor,

At the outset, we are highly grateful to you for allowing our submission to enter into review process of your prestigious journal. We are also thankful to the all respected reviewers for helping us to improve the quality of submission and to strengthen the managerial implications of the research. On behalf of all my co-authors**,** I would like to put on record their appreciation and valuable suggestions. Based on the reviewers' feedback, we have revised the entire paper. As, you will find, the revised manuscript incorporates the desired changes and shown in different colour (green).

Once again thank you for highlighting the key improvement/changes needed to give us a clear direction. We are looking forward to hearing from you with high spirit.

Please find the answers for the queries raised by the reviewers.

AUTHORS' RESPONSE TO REVIEWER'S COMMENTS

Reviewer #1:		
S. No	**Reviewer Comments**	**Authors Reponses**
1	The paper is very well written, its topic is interesting to the audience of IJPR and the methodology is clear and suitable to the topic.	The authors are thankful to the reviewer for his/her kind appreciation.
2	The references are authoritative and updated and the conclusions and implications for researchers and practitioners are clearly established.	The authors are thankful to the reviewer.
3	Although my mother tongue is not English I have found some weird expressions. Perhaps the paper could be benefited from a deep reread and corrections of Little mistakes. For example:	The authors are thankful to the reviewer for so minutely observing the research article. We really appreciate reviewers for his/her valuable feedback. The necessary corrections have been made in the paper.

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	Page 8 line 8: "Financial benefits rendered to the manufacturing organisation **is** always higher **is** case of". Are the two "is" correct?? Page 11 line 42-43: "demands for **treatment** of hybrid MCDM **treatment** of offshore". Are the two "treatment" correct? Page 23 line 29: "The test for sensitivity **is** extremely essential **is** context to framework". Are the two "is" correct?	Suggestions are incorporated and the sentence is rephrased. Suggestions are incorporated and the sentence is rephrased. Suggestions are incorporated and the sentence is rephrased.
4	It has been surprising to find in table 1 Data Privacy as one of the Offshore Outsourcing enablers. I have read 1 on the contrary that Data privacy could be one of the biggest problems or risk in offshore relations. Could the authors extend the discussion of table 1 in pages 7 and 9 to explain a little more why they include Data privacy as an offshore enabler?	The detail of inclusion of data privacy as an offshore outsourcing enabler is shown in section 2.1.
5	Although the methodology is clear it could be improved if the authors explain a Little more how they selected to the 6 experts and the 4 automotive business organisation that were used to assess the framework.	The selection procedure of experts and the organisation is described in Case Study.

Reviewer #2:		
S. No	**Reviewer Comments**	**Authors Reponses**
1	The research aims are interesting and very important to support offshore outsourcing in automotive industry. Especially in India, a growing market, industries must evaluate offshore outsourcing to stay competitive.	The authors are thankful to the reviewer for appreciating our research attempt.
2	Table 1 is very interesting. This sums up the offshore outsourcing enablers found in literature review. Nevertheless, authors could present enablers structured in categories: individual, technological, socio-cultural, organizational and managerial and strategic.	The authors are thankful to the reviewer. Table 1 represents the list of enablers extracted through literature review. However, the categorisation is done while developing the framework through involvement of experts as shown in Figure 2.

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3	In page 9, authors wrote "In order to have better understanding of MCDM approaches, readers may refer to (Rao 2007; Tzeng 2010). According to (Ishizaka and Nemery, 2014), [...]." I suggest that this sentence be written using different type of citation. As "In order to have better understanding of MCDM approaches, readers may refer to Rao (2007) and Tzeng (2010). According to Ishizaka and Nemery (2014), [...]."	As suggested by the reviewer, the sentences are rephrased accordingly. Please refer to revised manuscript.
4	Table 5-6 presents different formatting. Please check it.	As suggested by the reviewer, Table 5-6 are formatted uniformly.
5	The experts that took part of the research are not well identified. I know that the researchers can't show their identity. But I think it is important to inform expert's work experience, work area and professional training. This can increase the credibility of the article.	As suggested by the reviewer, the detail of experts is added in Section 4. Case Study.
6	In page 23 authors wrote: "The test for sensitivity is extremely essential is context to framework based studies to check its robustness". This sentence should be rewritten.	Suggestion is incorporated and the sentence is rewritten.

Reviewer #3:		
S. No	**Reviewer Comments**	**Authors Reponses**
1	This is a very interesting work. The authors clearly explained the aim of the work, the methodology used to pursue it, the results obtained as well as the limitations, implications and future research directions.	The authors are thankful to the reviewer for appreciating our research attempt.
2	According to the aim and scope of the journal, my main suggestion is to highlight the importance of the topic in the field of production research. My minor suggestions are: • Improve the quality of figures 3 and 4	The importance of the topic in the field of production research is highlighted in the Abstract, Introduction, Contributions, and Conclusions section of the revised paper. Suggested changes have been made.

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3	Consider the work published by Dou and Sarkis in 2010 ("A joint location and outsourcing sustainability analysis for a strategic offshoring decision")	As suggested by the reviewer, the recommended article is considered for present study.
4	As concern the literature review process, the authors include some details in the figure 1. Level 2 of the figure indicates that papers published from Taylor &Francis, Science direct - Elsevier, Springer, Emerald insight, and Inderscience have been included. These publishers are already in the Scopus database. Which journals have you selected? How many papers have you obtained from the first research? How many papers have been excluded since not focused on the topic? Have you considered also conference proocedings? My suggestion is to include more details in section 2 and, for your convenience, you may refer to the literature review framework proposed by Centobelli et al. in 2017 ("Developing the WH2 framework for environmental sustainability in logistics service providers: A taxonomy of green initiatives") and Tranfield et al. in 2003 ("Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review")	The authors agreed to the point that these journals are already included in the Scopus database. Necessary changes have been made in the revised manuscript (please refer Section 2. Literature review). The suggested studies have been included in the revised version of the paper.

Reviewer #4:		
S. No	**Reviewer Comments**	**Authors Reponses**
1	I read the work, carefully. I am happy to say that my opinion about the present work is positive, approximately. The paper has some positive outcomes. Also, the paper was written in a smooth manner.	The authors are thankful to the reviewer for appreciating our research attempt.

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2	The paper suffers from some minor/major weaknesses that I explain here after. **Abstract:** I consider that an abstract should not be an Introduction to a paper but a summary of the methodology and the more so of finding.	As suggested by the reviewer, the present abstract is modified and more description related to methodology and finding has been added.
3	**Novelty:** I would like to see more documented reasons about the novelty of the proposed method. Please explain, explicitly.	As suggested by the reviewer, the novelty of present research work is explained explicitly. Please refer Section 5 and Section 6.
4	**Evaluation:** I would like to see more results and analysis about the accuracy (or reliability) of the proposed method.	As suggested by the reviewer, description of results and accuracy of present method is added to Section 5.

The revised manuscript as per reviewers' feedback and 'International Journal of Production Research' requirement is submitted for your kind consideration.

We look forward to your favourable consideration in this regard.

Once again, we thank you profusely for your kind suggestions and time.

Warm regards

Yours sincerely,

With Warm Regards

Dr. Sachin K. Mangla

Corresponding author

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Hybrid BWM-ELECTRE based decision framework for effective offshore outsourcing adoption: a case study

Abstract

The present study seeks to develop a decision framework of enabler to help managers in offshore outsourcing adoption by focussing on the relevant enablers and their intensities. A hybrid Best Worst Method - ELimination and Choice Expressing REality approach is used to test the applicability of developed offshore outsourcing focused enabler's across four automotive business organisations in India and the adoption score of framework among case organisations is evaluated too. The intensity of offshore outsourcing focused enablers is analysed through Best worst method and the ranking of organisations and adoption index scores are computed through ELimination and Choice Expressing REality method. The developed framework possesses high adoption rate in offshore outsourcing initiatives across the case organisations. Findings of the study reveal that among the main enablers; managerial and strategic enabler holds the highest weight followed by technological enablers and organisational enablers. This study further presents the sensitivity analysis to check the robustness of developed framework by conducting experiments in different conditions. This research work will facilitate managers and professionals involved in practicing offshore outscoring initiatives and results in higher cost advantages on labor and raw material, increased economies of scale, and higher sustainable business development.

Keywords- Offshore outsourcing, Enablers, BWM, ELECTRE, MCDM, Automotive Organisations, Sustainable business development

Paper type- Research Paper

1. Introduction

The present industrial scenario has become challenging for both the old industry giants and new entrepreneurs (López and Ishizaka 2017). The old industry giants are continuously

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offering high quality products at premium price, while the new entrepreneurs are providing the same products at economical price to establish themselves in the market (Jensen 2012). In this sense, the manufacturers needs to be highly focused and proactive in their approach for sustainable business development (Herath and Kishore 2009). Simultaneously, constantly changing customer requirements for customised design, specifications and on time delivery requirements has also posed numerous challenges among the manufacturers (Gylling et al. 2015). These issues are comparatively managed by the service industries, while the manufacturing industries are still struggling to achieve the optimum solution (Gurtu, Searcy, and Jaber 2016). From managerial viewpoints, to take advantages of cheap labour and quick accessibility of raw materials and maintaining effective supply chain, the manufacturing industries are switching towards offshore outsourcing (Benito et al. 2013). Industries are struggling with high in-house production cost and to meet customers' changing preferences, which motivates them to adopt offshore outsourcing manufacturing initiatives. From an organisational context, practicing offshore outscoring initiatives can help managers in achieving higher cost advantages on labor and raw material, increased economies of scale, higher sustainable business development etc.

The offshore outsourcing gained higher popularity in the developing countries due to the availability of cheap labour and raw materials (Tjader, Shang, and Vargas 2010). The offshore outsourcing become a prime choice among the service as well as manufacturing organisations to maintain their profit margins (Wang and Song 2017). In context to service industries, the offshore outsourcing portrayed noticeable benefits but as far as manufacturing industries are concerned, due to existence of physical goods, still substantial work is needed to extract the desired benefits (Quinlan, Hampson, and Gregson 2013). To enhance the adoption rate of offshore outsourcing, many researchers suggested various enablers and or driving factors. By focussing on these enablers, offshore outsourcing initiatives can be efficiently accomplished (Lahiri and Kedia 2011).

Many researchers suggested different set of enablers to offshore outsourcing adoption (Tate et al. 2009; Mukherjee, Gaur, and Datta 2013; Mella and Pellicelli 2012), however majority of enablers are limited to service sector context. Besides, very few studies highlighted the enablers affecting the adoption of offshore outsourcing in manufacturing environment (Gylling et al. 2015; Quinlan, Hampson, and Gregson 2013). In addition to listing of enablers to offshore outsourcing, no study is available in literature which developed a framework for evaluating the intensity of relevant enablers. The related enablers will help in enhancing the

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offshore outsourcing success rate, but may not be equally important in terms of their relative influences. Hence, this becomes extremely essential to help managers to develop a decision framework for identifying and ranking of the enablers in practicing offshore outsourcing initiatives.

Specifically, the research objectives for the present study are defined as:

i. To develop a framework for identifying and ranking of the enablers influencing the adoption of offshore outsourcing;
ii. To test the applicability of developed framework in multiple case organisations.

To fulfil above-defined objectives, an exhaustive literature review is carried out. The list of enablers that facilitates the adoption of offshore outsourcing extracted through literature is discussed with the expert panel. After finalisation of enablers, a framework is developed and tested for applicability to four case organisations involved in offshore outsourcing initiatives. These case organisations are Original Equipment Manufacturers (OEMs) in automotive sector in India. These case organisations are leading organisations in their product category of passenger cars and trucks and have global presence. The passenger car manufactures offshores a key component i.e. transmission gearbox. Whereas, truck manufactures outsources suspension system. In this work, a hybrid Best Worst Method - ELimination and Choice Expressing REality (BWM – ELECTRE) Multi Criteria Decision Making (MCDM) approach has been employed to know the intensity and or relative importance of the enablers. Besides, based on the hybrid BWM-ELECTRE approach, the adoption rate of developed framework across four case organisations is evaluated. In line with this, a sensitivity analysis check is carried out to check the robustness of the developed framework.

The present study is organised into 7 sections including introduction. Literature review for this study is presented in Section 2. Section 3 explains the research methodology adopted and developed framework. Section 4 describes the application of developed framework across case organisations. Section 5 describes the study contributions and implications for researchers and practitioners. Section 6 portrays the conclusions, limitations and future scope of the study.

2. Literature Review

For effective adoption of offshore outsourcing, it is extremely significant to explore the various enablers/drivers/critical success factors reported in literature. For reviewing the

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literature, authors adopted the Systematic Literature Review (SLR) approach of Luthra et al. (2017), Centobelli, Cerchione, and Esposito (2017) and Tranfield, Denyer, and Smart (2003). Current and relevant papers were selected based on the following criteria:

(1) Articles should include Outsourcing and Offshoring and Decision Making implementation in production system. In addition, for literature search, following keywords were used; "Offshoring", "Outsourcing", "Drivers", "Success Factors", "Enablers", "Drivers", "Production System". Combinations of those keywords were used, which includes "Offshoring Enablers and Production System", "Outsourcing Enablers and Production System", "Offshoring Drivers and Production System", "Outsourcing Drivers and Production System", "Offshoring Success Factors and Production System", "Outsourcing Success Factors and Production System", "Offshore Outsourcing Enablers and Production System".

(2) Authors explored Scopus and Google Scholar databases to collect research articles. The collected studies were analysed using the keywords in abstract and main text of article to include/exclude the particular article. In addition, we also defined some more criteria in relation to inclusion/exclusion of the articles, which are given as (i) Articles written in English were only considered; (ii) peer-reviewed journals articles and book chapters, were only considered (conference proceedings were excluded).

(3) As the concept of offshore outsourcing originated in early 2000, thus, the time horizon selected for the study is year 2000-2017.

Considering these criteria, we scrutinize the collected literature followed by the forward snowball and backward snowball technique (Glock et al., 2014). In that way, articles relevant to this work are gathered. All articles were considered to be representative of the current body of knowledge associated with outsourcing and offshoring implementation, and drivers and enablers assists in decision making to outsourcing and offshoring in production research.

Further, the literature review for the present work is divided into three subsections.

2.1 Offshore outsourcing enablers

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There are various factors influencing the adoption of offshore outsourcing initiatives, which includes; institutional factors, organisational factors, technological factors, economical factors, social and behavioural factors etc. (Kinkel and Maloca 2009). Taking these factors into consideration, industry professionals may execute their outsourced projects effectively (Dou and Sarkis 2010). The basic need of offshore outsourcing is to reduce the overall manufacturing cost through cheap labour, raw materials and advanced information and communication technology. (Jensen 2012). The big industry giants are operating with motto of maximising profit with minimum investment, which also helping the developing nations to generate employment and uplift their economy (Maskell et al. 2007). The availability of quality manpower and capability to move up the value chain are the key enablers for successful adoption of offshore outsourcing projects (Dolgui and Proth 2013). The adoption of advanced information and communication technologies, data privacy, and utilising internet of things help in controlling and effective tracking of the project may be in-house or outsource (Dekkers 2011). Here, data privacy refers to the effective data privacy system that ensures the security of data involved in entire production system. It helps in boosting the confidence level of the organisation and maintaining the production quality standards.

Among the organisational factors, operational cost reduction, experience utilisation, scheduled training and education, and effective supply chain and logistics system are some of the critical enablers (Hätönen and Eriksson 2009; Ishizaka and Blakiston 2012; Kinkel and Maloca 2009). Many organisations kicked off the offshore outsourcing projects but fail to deliver the required quality product to their customer. This issue can be managed having a better control over the project through effective project management system, effective performance measurement system (Gurtu, Searcy, and Jaber 2016). Many organisations try to replicate the offshore outsourcing model of other organisation and results in failure (Benito et al. 2013). This is important to understand that every organisation has its own business environment, and especially the service and manufacturing domains (Weerakkody and Irani 2010).

Among the economic factors, it is suggested to consider the issues related to hidden costs, cost comparison and evaluation system, and government export policies (Mella and Pellicelli 2012). These factors strongly influence the successful accomplishment of any offshore outsourcing project. The currency values keep fluctuating at regular intervals. Hence, the management should carefully keep the tolerance of exchange rate fluctuations (Jensen 2012). Financial benefits rendered to the manufacturing organisation is always higher in case of

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offshore outsourcing (Lahiri and Kedia 2011). This is a win-win situation for both the parties and also helps in developing domestic industries. The set of enablers influencing the offshore outsourcing adoption reported by various researchers in literature are shown in Table 1.

Table 1:- Offshore outsourcing enablers reported in literature

S. No.	Offshore outsourcing enablers	References
1	Effective management leadership skills and long term vision	(Mehta and Mehta 2017; Lahiri and Kedia 2011; Jensen 2012)
2	Availability of resources (financial and technological)	(Herath and Kishore 2009; Kim et al. 2017; Bardhan, Whitaker, and Mithas 2006)
3	Effective communication system	(Mehta and Mehta 2017; Herath and Kishore 2009)
4	Supplier commitment	(Weerakkody and Irani 2010; Gurtu, Searcy, and Jaber 2016)
5	Availability of quality manpower	(Gylling et al. 2015; Wang and Song 2017)
6	Capability to move up the value chain	(Jensen 2012; Lahiri and Kedia 2011)
7	Advanced ICT	(Kumar, Zampogna, and Nansen 2010; Mehta and Mehta 2017; Jensen 2012)
8	Appropriate estimation of project cost	(Herath and Kishore 2009; Kim et al. 2017; Lahiri and Kedia 2011)
9	Effective performance measurement system	(Mehta and Mehta 2017; Kumar, Zampogna, and Nansen 2010)
10	Utilisation of expert professional	(Mukherjee, Gaur, and Datta 2013; Tate et al. 2009)
11	Effective project management	(Quinlan, Hampson, and Gregson 2013; Wang and Song 2017; Weerakkody and Irani 2010)
12	Develop own offshore outsourcing strategy	(Tjader, Shang, and Vargas 2010; Benito et al. 2013)
13	Overcome the cultural differences	(Gurtu, Searcy, and Jaber 2016; Mehta and Mehta 2017)
14	Selection of effective quality management tools	(Benito et al. 2013; Herath and Kishore 2009)
15	Employee involvement and empowerment	(Jensen 2012; Mehta and Mehta 2017)
16	Protection for intellectual property rights	(Lahiri and Kedia 2011; Gurtu, Searcy, and Jaber 2016)
17	Tolerance for exchange rate fluctuations	(Mehta and Mehta 2017; Mella and Pellicelli 2012)
18	Appropriate knowledge of government policies	(Mukherjee, Gaur, and Datta 2013; Tate et al. 2009)
19	Data privacy	(Mella and Pellicelli 2012; Mehta and Mehta 2017)
20	Consideration of different hidden costs	(Kumar, Zampogna, and Nansen 2010; Bardhan, Whitaker, and Mithas 2006)
21	Consideration of human factors	(Mehta and Mehta 2017; Kim et al. 2017)
22	Strong application of modern statistical and optimisation techniques	(Tjader, Shang, and Vargas 2010; Weerakkody and Irani 2010)

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23	Focussed alignments of project objectives, organisational aim, and customer requirements	(Tate et al. 2009; Quinlan, Hampson, and Gregson 2013; Gurtu, Searcy, and Jaber 2016)
24	Transparency and strong connection with vendors	(Gylling et al. 2015; Kim et al. 2017)
25	Continuous innovation strategy	(Jensen 2012; Benito et al. 2013)
26	Scheduled training and education system	(Mehta and Mehta 2017; Lahiri and Kedia 2011)
27	Experiential sophistication	(Gurtu, Searcy, and Jaber 2016; Mehta and Mehta 2017)
28	Focussed R&D cell	(Kumar, Zampogna, and Nansen 2010; Bardhan, Whitaker, and Mithas 2006)
29	Appropriate rewards and recognition system	(Kim et al. 2017; Jensen 2012)
30	Multi-stage quality check system	(Mehta and Mehta 2017; Lahiri and Kedia 2011)
31	Strong customer feedback system	(Kim et al. 2017; Kumar, Zampogna, and Nansen 2010)
32	Quality information and analysis	(Tjader, Shang, and Vargas 2010; Quinlan, Hampson, and Gregson 2013)

2.2 Decision making techniques and offshore outsourcing

Multi-criteria decision making (MCDM) approaches assist researchers as well as practitioners in making strategic decisions on their complex industry problems (Mangla, Madaan, and Chan 2013; Bhattacharya et al. 2014). MCDM approaches include two basic terms for problem solving; criteria and alternatives. In the context of present study criteria is referred to enablers, whereas; alternatives will be referred to the organisations, whose ranking is computed in later part of the study (Yadav and Desai 2017b). In order to have better understanding of MCDM approaches, readers may refer to Rao (2007) and Tzeng (2010). According to Ishizaka and Nemery (2014), "It is extremely critical to choose the appropriate MCDM approach applicable for a specific problem". Each MCDM approach has its own uniqueness and applicability which provides flexibility to researchers for making decisions on industry problems (Khemiri et al. 2017).

Several researchers have utilised MCDM approaches in offshore outsourcing domain such as fuzzy AHP, Data Envelopment Analysis (DEA), Decision Making Trail and Evaluation Laboratory (DEMATEL), Analytical Network Process (ANP), Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE), VIKOR etc. Prakash and Barua (2016) used a combined MCDM approach for selecting and evaluating third party reverse logistics partner for Indian electronics manufacturing industry. Rajaeian, Cater-Steel, and Lane (2017) conducted a systematic literature review of MCDM approaches employed by researchers in outsourcing domain. Their findings indicated that most of the MCDM approaches used by researchers are in hybrid format which strengthens the study results. Liou

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et al. (2011) proposed a hybrid model for outsourcing provider selection by ranking the outsourcing providers. Similar work was carried out by Hsu, Liou, and Chuang (2013) where they integrated DEMATEL and ANP with modified grey relation theory for outsourcing provider selection. Lin et al. (2010) employed a novel hybrid MCDM approach for outsourcing vendor selection in a semiconductor manufacturing company in Taiwan. Uygun, Kaçamak, and Kahraman (2014) used integrated DEMATEL and fuzzy ANP techniques for selecting outsourcing provider for a telecommunication company.

Problem solving through MCDM approach is always carried out at two levels. The first level includes exploring the available criteria and computing their intensities (weights). The literature reveals several MCDM approaches for the purpose which includes; Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), Decision Making Trial and Evaluation Laboratory (DEMATEL), Simple multi-attribute rating technique (SMART), Weighted Sum Method (WSM), Best Worst Method (BWM) and many more (Yadav and Desai 2017a). From the pool of methods; AHP has been widely used by researchers in literature. Many researchers have extended its fuzzy version to enhance the preciseness of the obtained solutions (Gylling et al. 2015). However, AHP possess certain limitations; as it utilises an unstructured way comparisons that many times leads to inconsistencies and while making comparisons relative allotment of fuzzy scores at times seems to different for number of criteria (Rezaei 2015a). Hence, to overcome the above issue, Best Worst Method (BWM) was proposed by Jafar Rezaei in 2015. BWM helps to tackle the above discussed issues and provides systematic weight assessment procedures (Rezaei, Hemmes, and Tavasszy 2016). So, for the present study BWM is adopted for computation of enabler weights.

The second level in MCDM approaches includes ranking and prioritisation of alternatives. For this purpose, several outranking methods such Complex Proportional Assessment (COPRAS), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Evaluation of Mixed Data (EVAMIX), PROMETHEE, ELECTRE etc. are reported in literature (Khemiri et al. 2017). Each method possesses its own credibility and applicability (Yadav, Seth, and Desai 2017). However, in case where the number of alternatives is very high ELECTRE is normally considered as a prime choice as it offers flexibility to the researchers to compare each alterative separately on the basis of individual criteria (Sevkli 2010; Yadav and Desai 2016). However, it doesn't even require the normalisation of selected variables (Irawan et al. 2017). While ranking of alternatives, ELECTRE also considers the

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beneficial and non-beneficial criteria (López and Ishizaka 2017). Hence, for the present study ELECTRE is employed to rank the alternatives and compute their adoption index.

2.3 Gaps identified through literature

Based on the literature review, following gaps are identified.

- Most of the studies on offshore outsourcing focussed on identification of enablers in context to service industries, however; the context of manufacturing industries particularly automotive sector seems to be unexplored.
- Very few studies presented the offshore outsourcing enablers related to manufacturing industries but none of the studies evaluated the intensity of the relevant enablers.
- Limited number of studies presented the framework to enhance the adoption of offshore outsourcing. However, the proposed frameworks available in literature lack verification and needs case study applications to justify its applicability.
- Some frameworks are validated through case studies but no provided the robustness of their developed framework through sensitivity analysis test.
- Many studies in literature listed out the benefits of offshore outsourcing in context to the project delivering concern, but very few studies highlighted the insights and facilitators for project executing concerns.
- Strategy and decision making based problems related to offshore outsourcing in literature reveals that MCDM techniques and statistical analysis can assist managers in problem solving.

The above discussed issues exposes the gaps in literature and clearly demands for treatment of hybrid MCDM approaches to offshore outsourcing enablers. This will further provide a structured guidance to researchers and practitioners to develop roadmap in effective offshore outsourcing adoption. This also justifies the requirement of present study.

3. Research methodology

The research methodology adopted for the present work is shown in Figure 1. For identification of key offshore outsourcing enablers a critical review of literature is carried out. For conducting literature review, Scopus and Google Scholar and Google databases are employed and a list of enablers was prepared. The list of tabulated enablers was presented before the decision panel for finalising the enablers and developing the framework accordingly. The selected enablers were categorised under five major groups namely; managerial and strategic enablers, organisational enablers, technological enablers, socio-

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cultural enablers and individual enablers. The decision panel (please refer Section 4) was further utilised to take inputs for hybrid BWM-ELECTRE approach. Based on their inputs, a decision framework to enhance the adoption of offshore outsourcing is developed as shown in Figure 2. The developed framework is then employed by taking four automotive business organisations in India. Hybrid BWM-ELECTRE approach assists not only to compute the relative importance weight of enablers, but also ranked the organisations to assess the adoptability of developed framework. This also shows the adoption index score of each organisation and finally a sensitivity analysis is carried out to check the robustness of the developed framework.

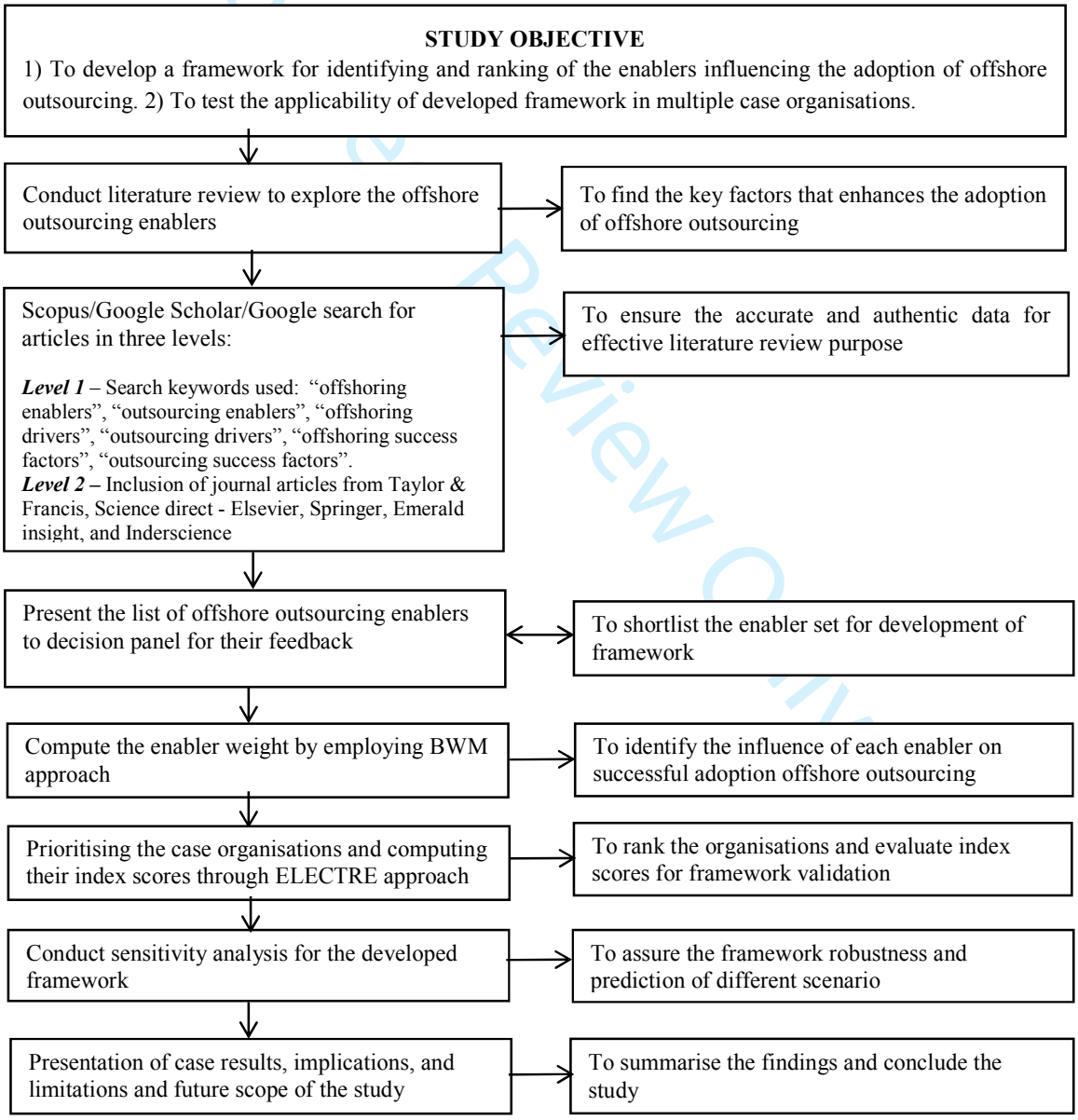

Figure 1:- Research methodology adopted for this study

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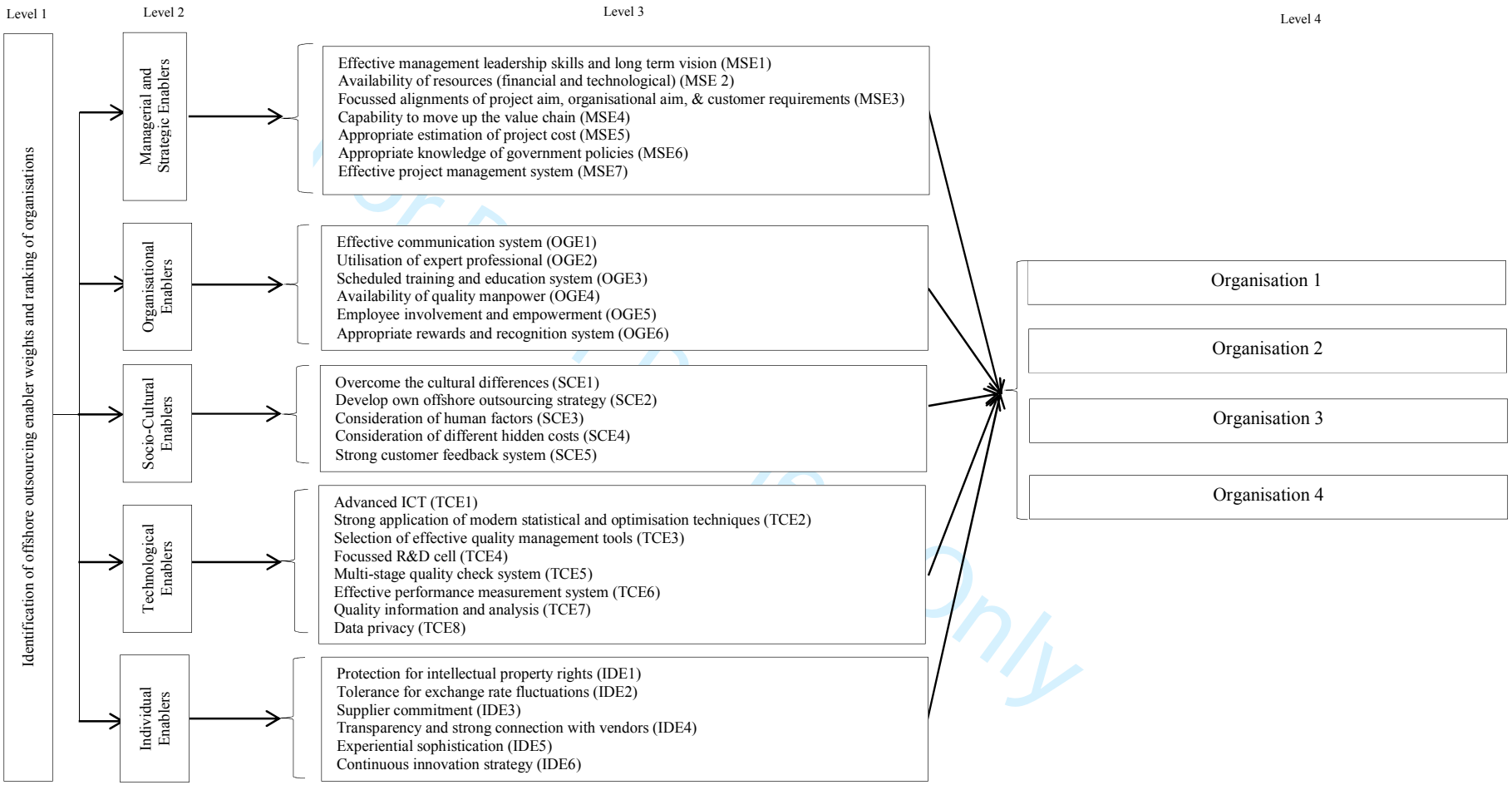

Figure 2:- Developed framework to enhance the adoption of offshore outsourcing

3.1 Best Worst Method (BWM)

Best worst method (BWM) was first proposed by Jafar Rezaei in 2015 to solve MCDM problems. In the case of multi criteria problems, the entire problem is carried out in two stages. First stage includes finding the weights of attributes/criteria and the second stage describes the selection of alternatives with respect to the weights of the attributes (Rezaei 2015a). According to BWM method, the most significant and least significant criteria are identified by the decision maker (Salimi and Rezaei 2016).There are several other methods, such as Analytic Hierarchy Process (AHP) and Simple Multi-Attribute Rating Technique (SMART) employed by researchers to calculate the attribute weights (Yadav, Seth, and Desai 2018; Gupta and Barua 2016). Compared to these methods, BWM is more consistent and used extensively by researchers as shown in Table 2.

Table 2:- Application of Best Worst Method

Author	**Area of Application**
(Rezaei 2015b)	Description of Best Worst Method
(Rezaei 2015a)	Description of properties of BWM
(Rezaei, Wang, and Tavasszy 2015)	Linking supplier development to supplier segmentation
(Chitsaz and Azarnivand 2017)	Water Scarcity Management
(Gupta and Barua 2016)	Technological innovation for Indian MSMEs
(Hafezalkotob and Hafezalkotob 2016)	Risk-based material selection process
(Huang and Moh 2016)	Application of Perron Theorem in multi criteria decision making
(Mou, Xu, and Liao 2016)	Fuzzification of BWM
(Ren, Liang, and Chan 2016)	Urban sewage sludge
(Rezaei, Hemmes, and Tavasszy 2016)	Surface transportation of air freight
(Rezaei, Nispeling, et al., 2016)	Supplier Selection
(Salimi and Rezaei 2016)	Measuring efficiency of industry-institute projects

The basic steps involved in solving the BWM are discussed below (Rezaei 2015a,b): -

1) Identify the set of decision criteria. Let the criteria for which the weights are to be calculated as c_1, c_2, c_3, c_4…….. c_n.
2) Identify the best and the worst criteria: This step includes defining the best and worst criteria among the available criteria.
3) Identify the preference of best criteria over other all other criteria by involving the numbers between 1 to 9. This basically results in representing the best to other vectors

$$A_B = (a_{1B}, a_{2B}, a_{3B}, \ldots a_{nB}) \quad \text{Eq. (1)}$$

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4) Identify the preference of worst criteria over other all other criteria by involving the numbers between 1 to 9. This basically results in representing the worst to other vectors

$A_w = (a_{1w}, a_{2w}, a_{3w}, \ldots a_{nw})$ Eq. (2)

5) Calculate the optimal weights ($w_1^*, w_2^*, w_3^*, \ldots w_n^*$). The procedure for calculating the optimal weights is illustrated in Appendix-A.

After calculating the optimal weights the next step includes checking the consistency of the identified weights. The needed consistency index table is also provided in Appendix A.

We can evaluate the consistency ratio using ξ^* and corresponding consistency index by the below mentioned formula:

$$\text{Consistency ratio} = \frac{\xi^*}{Consistency\ Index} \quad \text{Eq. (3)}$$

3.2 ELECTRE method

ELECTRE method was developed by Professor Bernard Roy as an outranking method for solving MCDM problems. Generally, in outranking techniques we only made pair wise comparisons between the available attributes and alternatives (Sevkli 2010). However, ELECTRE method possess a unique feature by comparing all the alternatives with each criteria (Kadziński and Ciomek 2016). This is the reason ELECTRE has been employed extensively by researchers as illustrated in Table 3.

Table 3:- Recent applications of ELECTRE Method

Author	Area of Application
(Mousavi, Gitinavard, and Mousavi 2017)	Renewable energy policy selection
(Kadziński and Ciomek 2016)	Preference Modelling and outranking
(Naghiu et al. 2016)	Solar radiation panel selection
(Wu et al. 2016)	Wind power station site selection
(Ishizaka and Nemery 2014)	Assigning m/c to incomparable maintenance strategies
(Lian and Ke 2014)	Agricultural product recommendation
(Petrović et al. 2014)	EU digital agenda targets

The steps involved in applying the ELECTRE method are discussed as follows (Mousavi, Gitinavard, and Mousavi 2017):

1) Prepare a decision table: The initial step includes the finalisation of the list of attributes as well as alternatives. This step helps in building the hierarchical structure of the problem.

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2) Evaluation of weights: The second step includes the calculation of attribute weights which can be evaluated by using several weight assessment techniques such AHP, WASPAS, SWARA, SMART, BWM etc. For the present study the weights are calculated by Best Worst method.

3) Find the concordance matrix: All the available attributes are grouped together and are assessed whether they are beneficial or non-beneficial. In case of beneficial attribute the highest possible value is required whereas in case of non-beneficial attribute the lowest possible value is taken. For the case of function f (a_1), a_1 is the score of alternative and w_j is the weight of attribute j, then the concordance index C (a_1,a_2) is denoted as:

$$C(a_1,a_2) = \sum_{j=1}^{M} wj * cj(a1, a2) \quad \text{Eq. (4)}$$

Here the value of c_j (a_1,a_2) can be calculated as:

$$C_j(a_1,a_2) = \begin{cases} 1, & if \quad fj(a1) + qj \geq fj(a2) \\ 0, & if \quad fj(a1) + pj \leq fj(a2) \\ \frac{fj(a1)+pj-fj(a2)}{pj-qj} & if \quad otherwise \end{cases} \quad \text{Eq. (5)}$$

The concordance index C (a_1,a_2) basically indicates the relative importance of one alternative over the other.

4) Find the discordance index: In this step, firstly the veto threshold (v_j) is calculated. By the veto threshold the possibility of a_1 over a_2 can be refused completely when the second alternative value is greater than the sum of first alternative and veto threshold. The discordance index of each attribute d_j(a_1,a_2) can be calculated as:

$$D_j(a_1,a_2) = \begin{cases} 0, & if \quad fj(a1) + pj \geq fj(a2) \\ 1, & if \quad fj(a1) + vj \leq fj(a2) \\ \frac{fj(a2)-pj-fj(a1)}{vj-pj} & if \quad otherwise \end{cases} \quad \text{Eq. (6)}$$

The discordance index D(a_1,a_2) basically indicates the relative worstness of one alternative over the other.

5) Find the Credibility index: In this step, the credibility index represents the strength of assertion that "first alternative is at least as good as alternative 2". The creditability index can be calculated as described below:

$$S(a_1,a_2) = \begin{cases} C(a1,a2), & if \quad C(a1,a2) \geq dj(a1,a2) \quad \forall j \\ C(a1,a2) * \prod_{j \in J(a1,a2)} \frac{1-dj(a1,a2)}{1-C(a1,a2)} & otherwise \end{cases} \quad \text{Eq. (7)}$$

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6) Find the superiority ratio: Final step includes finding the superiority ratio based on which the final ranking of the alternatives can be done.

4. Case Study

The developed framework is tested for its applicability across four automotive case business organisations involved in offshore outsourcing business. Similar case validation of framework was carried out by (Thanki and Thakkar 2016). This type of case application strengthens the framework and also generates the adoption index scores (Yadav, Seth, and Desai 2018), through which the adoption level of any process across each organisation can be compared efficiently.

4.1 Background of case organisations

In order to conduct the case study, a total of 12 automotive business organisations were contacted. Out of these, four organisations finally agreed to participate in present research work. In this way, we selected four automotive organisations operating in India as the case study. The case organisations were selected based on following key parameters:

(i) organisations are established as OEMs in the automotive sector,

(ii) organisations have global presence,

(iii) organisations are involved in offshoring and outsourcing initiatives in their value chain activities.

Table 4 summarises the case organisations.

Table 4:- Case organisations descriptions

	Organisation 1 (OG1)	**Organisation 2 (OG2)**	**Organisation 3 (OG3)**	**Organisation 4 (OG4)**
Product	Passenger Car	Passenger Car	Truck	Truck
offshore and outsourcing initiatives	Gear Box	Gear Box	Suspension	Suspension
Number of employees	79,558	13,259	11,906	6745
Headquarters	Mumbai, India	New Delhi, India	Chennai, India	Kolkata, India
Net income	$4.7 billion	$1.2 billion	$190 million	$ 12 million

As the globalization has enabled low-cost developing countries like India to compete with Western companies, which forced these Indian automotive organisations to fragment production processes across multiple regions. Designing and manufacturing key component

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like gearbox and suspension system is highly costly and needs highly specialized engineering skills. These automotive organisations offshore and outsources the key vehicle components (gearbox and suspension system) to reduce costs and stay competitive in the market place. Top management of the case organisations is committed for higher quality and they are involved in a project *"Offshore and Outsourcing Initiatives"*. Management has a desire to know and evaluate the enablers to reveal their relative intensities of importance for successful offshore outsourcing adoption initiatives in industry. Management also intends to employ a framework to evaluate their adoption score and develop decision plans in effective offshore outsourcing adoption accordingly. For the purpose of this work, a decision panel consisting of 6 experts from four automotive business organisations involved in offshore outsourcing was developed. The experts of decision panel possess the experience of more than 8 years of off-shoring and outsourcing activities. In the decision panel, there were two Supply Chain Managers, two Production and Design Engineers and two Logistics and Warehouse Managers. All the experts are highly skilled in decision making.

4.2 Identification of enabler weights

The decision panel finalised the categorisation of selected enablers into five major groups - managerial and strategic enablers (MSE), organisational enablers (OGE), technological enablers (TCE), socio-cultural enablers (SCE), and individual enablers (IDE) as shown in Figure 2. The next step is to identify the enabler weights and respective intensities which are computed using BWM. Based on procedural steps of BWM, the best and worst comparisons made by decision panel are tabulated as shown in Table 5-6. Due to limitation of space, only the comparisons made for main criteria enablers are shown.

Table 5:- Best-to-Others (BO) vectors from 6 experts

Expert No.	Best	MSE	OGE	SCE	TCE	IDE
1	MSE	1	4	6	2	5
2	MSE	1	4	5	4	6
3	MSE	1	5	2	6	4
4	OGE	3	1	6	3	4
5	TCE	3	5	4	1	5
6	SCE	4	2	1	3	4

Table 6:- Others-to-Worst (OW) vectors from 6 experts

Expert No.	Worst	MSE	OGE	SCE	TCE	IDE
1	SCE	7	3	1	6	3

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2	IDE	5	4	2	3	1
3	TCE	6	2	4	1	3
4	SCE	5	6	1	4	2
5	OGE	4	1	2	6	2
6	IDE	2	6	7	4	1

Table 7 represents the main enablers weights obtained through BWM. These weights represent the respective intensities of main enablers.

Table 7:- Main enablers weights

Expert No.	MSE	OGE	SCE	TCE	IDE	ξ^L
1	0.439	0.131	0.058	0.263	0.105	0.087
2	0.491	0.155	0.124	0.155	0.071	0.131
3	0.448	0.102	0.256	0.064	0.128	0.064
4	0.181	0.443	0.0568	0.181	0.136	0.102
5	0.192	0.074	0.144	0.473	0.115	0.103
6	0.127	0.255	0.382	0.170	0.063	0.102
Final weights.	0.313	0.193	0.170	0.218	0.103	0.098

Similar procedure is carried out to find the weights and respective intensities of sub enablers as shown in Table 8.

Table 8:- Global weights of offshore outsourcing enablers

Main Criteria	Main Enablers Wt.	Sub Enabler	ξ^L	Local Wt.	Global Wt.
Managerial and Strategic enablers (MSE)	0.313	MSE1	0.119	0.083	0.026
		MSE2		0.321	0.101
		MSE3		0.213	0.067
		MSE4		0.203	0.064
		MSE5		0.045	0.014
		MSE6		0.091	0.029
		MSE7		0.041	0.013
Organisational enablers (OGE)	0.193	OGE1	0.094	0.086	0.017
		OGE2		0.318	0.062
		OGE3		0.255	0.050
		OGE4		0.044	0.009
		OGE5		0.185	0.036
		OGE6		0.109	0.021
Social-Cultural enablers (SCE)	0.170	SCE1	0.073	0.269	0.046
		SCE2		0.207	0.035
		SCE3		0.180	0.031
		SCE4		0.227	0.039
		SCE5		0.115	0.020

Technological enablers (TGE)	0.218	TGE1	0.080	0.079	0.017
		TGE2		0.301	0.066
		TGE3		0.083	0.018
		TGE4		0.165	0.036
		TGE5		0.211	0.046
		TGE6		0.069	0.015
		TGE7		0.036	0.008
		TGE8		0.054	0.012
Individual enablers (IDE)	0.103	IDE1	0.053	0.242	0.025
		IDE2		0.177	0.018
		IDE3		0.157	0.016
		IDE4		0.180	0.019
		IDE5		0.087	0.009
		IDE6		0.153	0.016

4.2 Organisational index scores

The weights identified through BWM approach used as inputs to ELECTRE method for computing the organisational index scores. The experts from four automotive case organisations are asked to adopt the developed framework and accordingly after six months duration, they are asked to report the depth of penetration of each enabler into their organisations. Based on the inputs of selected experts, an initial comparison matrix for ELECTRE is developed as shown in Table 9.

Table 9:- Initial comparison of matrix for ELECTRE

Main Criteria	Sub-Criteria	OG1	OG2	OG3	OG4
Managerial and Strategic enablers (MSE)	MSE1	7.972	7.916	6.985	7.812
	MSE2	9.425	9.688	9.417	9.333
	MSE3	8.983	8.755	8.25	8.349
	MSE4	8.75	8.955	8.989	8.933
	MSE5	5	6.277	4.361	8.083
	MSE6	7.305	8.388	7.8	4.694
	MSE7	4.694	5.638	4.667	6.944
Organisational enablers (OGE)	OGE1	6.944	5	7.583	8.389
	OGE2	9.188	8.933	8.883	8.75
	OGE3	8.388	9.283	8.589	7.111
	OGE4	6.977	6.75	5	4.667
	OGE5	8.361	9.111	8.128	3.694
	OGE6	7.922	6.667	6.333	5.333
Social-Cultural enablers (SCE)	SCE1	7.961	8.694	8.722	4.694
	SCE2	5.333	8.917	7.922	6.583
	SCE3	6.694	8.306	8.465	4.667
	SCE4	7.583	8.817	8.167	7.583

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	SCE5	6.694	6.972	7.972	8.083
Technological enablers (TGE)	TGE1	5.638	7.25	7.75	7.417
	TGE2	8.348	9.333	8.333	8.478
	TGE3	4.694	5.333	6.333	8.056
	TGE4	6.694	8.127	8.722	7.983
	TGE5	7.416	9.261	9.394	8.394
	TGE6	5.666	6.972	6.694	7.75
	TGE7	6.916	7.75	6.583	4
	TGE8	6.838	7.417	7.75	5.667
Individual enablers (IDE)	IDE1	6.694	8.028	7.361	7.817
	IDE2	6.744	8.056	7.333	6.839
	IDE3	5	7.583	5.694	8.389
	IDE4	6.238	7.583	8.167	6.588
	IDE5	5.666	4.361	3.694	6.978
	IDE6	4.694	7.583	8.333	4.361

The overall concordance matrix is developed using Eqs. (4-5). It shows the combined relative importance of one alternative over the other across all the enablers. Similarly, Eq (6) is used to compute the discordance matrix, whereas the credibility index matrix is calculated through Eq (7) which indicates that one alternative is at least as good as alternative 2. By taking its row sum and column sum; the concordance credibility and discordance credibility is calculated. However, their ratio represents superiority ratio through which the final ranking of organisation is computed as shown in Table 10.

Table 10:- Final ranking of organisations

Organisation	Concordance Credibility	Discordance Credibility	Superiority Ratio	Rank
OG1	2.306	3.2246	0.715127458	3
OG2	3.7837	1.617	2.339950526	1
OG3	3.2846	3.1957	1.027818631	2
OG4	2.1845	3.5215	0.620332245	4

For computing the each organisation's adoption index scores, the sub-criteria weights are utilised as shown in Table 11.

Table 11:- Initial comparison of matrix for ELECTRE

Sub-Criteria	Weights	OG1	OG2	OG3	OG4
MSE1	0.026	0.208	0.207	0.182	0.204
MSE2	0.101	0.950	0.977	0.949	0.941
MSE3	0.067	0.601	0.586	0.552	0.558
MSE4	0.064	0.557	0.570	0.572	0.569

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MSE5	0.014	0.071	0.089	0.062	0.114
MSE6	0.029	0.209	0.240	0.223	0.134
MSE7	0.013	0.061	0.074	0.061	0.091
OGE1	0.017	0.115	0.083	0.126	0.139
OGE2	0.062	0.566	0.551	0.548	0.539
OGE3	0.050	0.416	0.460	0.426	0.352
OGE4	0.009	0.060	0.058	0.043	0.040
OGE5	0.036	0.299	0.326	0.291	0.132
OGE6	0.021	0.168	0.141	0.134	0.113
SCE1	0.046	0.366	0.400	0.401	0.216
SCE2	0.035	0.188	0.315	0.280	0.232
SCE3	0.031	0.205	0.255	0.259	0.143
SCE4	0.039	0.293	0.341	0.316	0.293
SCE5	0.020	0.131	0.137	0.157	0.159
TGE1	0.017	0.097	0.125	0.133	0.128
TGE2	0.066	0.548	0.613	0.547	0.557
TGE3	0.018	0.085	0.097	0.115	0.146
TGE4	0.036	0.241	0.293	0.314	0.288
TGE5	0.046	0.341	0.426	0.433	0.386
TGE6	0.015	0.085	0.105	0.101	0.117
TGE7	0.008	0.054	0.061	0.051	0.031
TGE8	0.012	0.080	0.087	0.091	0.067
IDE1	0.025	0.168	0.201	0.184	0.196
IDE2	0.018	0.124	0.148	0.135	0.126
IDE3	0.016	0.081	0.123	0.092	0.136
IDE4	0.019	0.116	0.141	0.152	0.122
IDE5	0.009	0.051	0.039	0.033	0.063
IDE6	0.016	0.074	0.120	0.132	0.069
Adoption Index Score		**7.628**	**8.404**	**8.111**	**7.417**

4.3 Sensitivity analysis

The test for sensitivity is extremely essential in context to framework based studies to check its robustness (Patil and Kant 2014; Yadav and Desai 2017b). Sensitivity analysis ensures the applicability of the developed framework and also predicts its behaviour in varied situations ((Mangla, Kumar, and Barua 2015; Gupta and Barua 2017). For the present study, sensitivity analysis is conducted by altering the weights of all the enablers and then observing the changes in the final index scores of the selected organisations. To assess the framework robustness, 32 experiments are conducted in two different slots to observe the variations in index scores. For the experiments conducted in each slot, one enabler weight is kept constant and accordingly the weight of other enablers is varied. In similar manner, remaining 31

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experiments are carried out. The experiments are carried out in two slots with given conditions (A) and (B) as described in Table 12.

Table 12:- Experiment details of sensitivity analysis

Exp. No.	(A) At fixed wt.= 0.15 variable wt. = 0.0290				(B) At fixed wt.= 0.1 variable wt. = 0.0274			
	OG1	OG2	OG3	OG4	OG1	OG2	OG3	OG4
1	7.048	7.762	7.391	7.056	6.994	7.753	7.415	7.011
2	7.226	7.979	7.689	7.242	7.097	7.879	7.587	7.119
3	7.172	7.865	7.546	7.122	7.066	7.812	7.504	7.049
4	7.144	7.889	7.636	7.193	7.049	7.827	7.557	7.091
5	6.684	7.561	7.069	7.089	6.783	7.637	7.228	7.031
6	6.967	7.820	7.491	6.674	6.947	7.786	7.473	6.790
7	6.647	7.483	7.107	6.949	6.761	7.591	7.250	6.950
8	6.922	7.404	7.464	7.126	6.921	7.546	7.457	7.052
9	7.197	7.887	7.623	7.171	7.080	7.825	7.549	7.078
10	7.099	7.930	7.587	6.970	7.023	7.850	7.529	6.962
11	6.926	7.619	7.147	6.670	6.923	7.670	7.274	6.788
12	7.096	7.908	7.531	6.551	7.022	7.838	7.496	6.719
13	7.042	7.609	7.311	6.752	6.990	7.664	7.368	6.835
14	7.047	7.857	7.604	6.674	6.993	7.808	7.538	6.790
15	6.725	7.88	7.506	6.905	6.807	7.824	7.481	6.924
16	6.892	7.810	7.567	6.670	6.903	7.781	7.517	6.788
17	7.001	7.872	7.536	7.028	6.966	7.817	7.499	6.995
18	6.892	7.646	7.512	7.089	6.903	7.686	7.485	7.031
19	6.762	7.680	7.485	7.007	6.828	7.706	7.469	6.983
20	7.094	7.936	7.556	7.137	7.021	7.853	7.510	7.059
21	6.647	7.445	7.311	7.086	6.761	7.570	7.368	7.029
22	6.892	7.788	7.604	7.077	6.903	7.768	7.538	7.023
23	6.980	7.927	7.686	7.127	6.955	7.848	7.586	7.053
24	6.766	7.646	7.355	7.048	6.830	7.686	7.394	7.007
25	6.919	7.742	7.342	6.588	6.919	7.741	7.386	6.741
26	6.909	7.701	7.485	6.793	6.914	7.717	7.469	6.859
27	6.892	7.776	7.437	7.056	6.903	7.761	7.441	7.012
28	6.898	7.779	7.433	6.936	6.907	7.763	7.439	6.942
29	6.684	7.721	7.233	7.126	6.783	7.729	7.323	7.052
30	6.836	7.721	7.536	6.906	6.871	7.729	7.499	6.924
31	6.766	7.326	6.987	6.953	6.830	7.501	7.181	6.952
32	6.647	7.721	7.556	6.633	6.761	7.729	7.510	6.766

Different behaviour of framework under given conditions can be observed in Figure 3 and Figure 4. The results of sensitivity analysis reveal that there is very limited variation (around 2.24 per cent) among the index scores of the four case organisations when tested for

sensitivity. Similarly, the rank of the organisations is changed in only 3 experiments out of the total 64 experiments conducted. This clearly enhances the adoptability of the present framework.

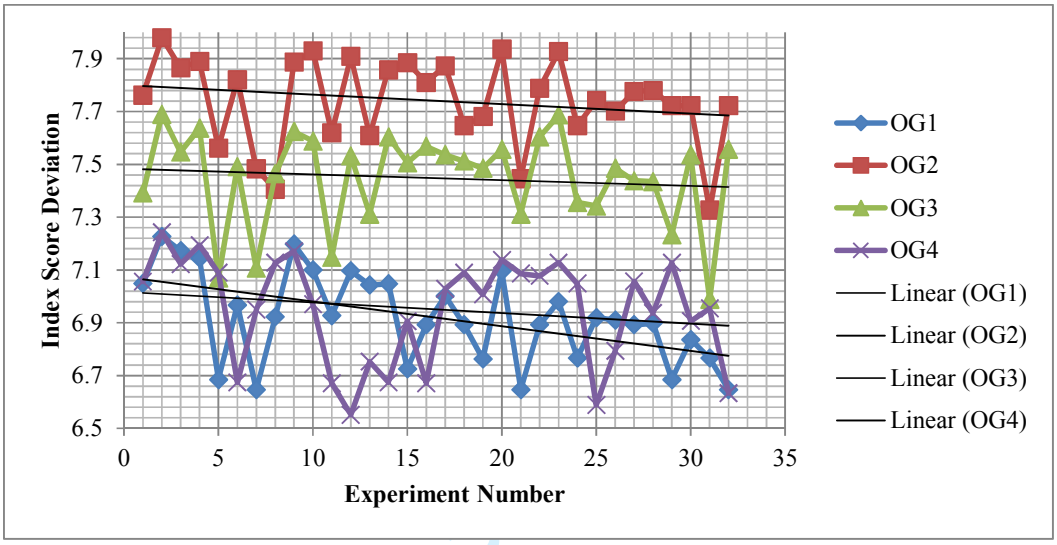

Figure 3:- Sensitivity analysis for condition (A)

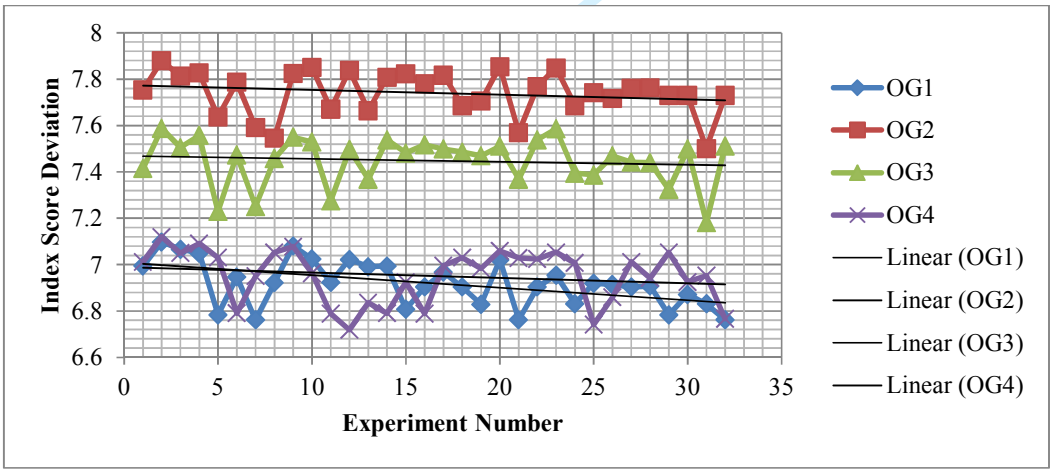

Figure 4:- Sensitivity analysis for condition (B)

5. Discussions

Evidently, the offshore outsourcing projects offers high financial benefits to the manufacturing sector of developing economies, however, it also demands top quality products comply with the international standards. Hence, it becomes extremely essential for

the manufacturers to upgrade their production standards and overall organisational culture to fulfil their client requirements. The results of the present study reveals that among the main criteria enablers; managerial and strategic enablers holds the highest weight (0.313) followed by technological enablers (0.218), organisational enablers (0.193), socio-cultural enablers (0.170) and individual enablers (0.103). It clearly indicates that strategic decisions of management and long vision policies enhance the organisational capability which enables them to grab offshore outsourcing projects. By upgrading the technological database and using advance information and communication technology, the manufacturers gets flexibility to produce highly customised products by maintaining high quality standards. It is interesting to observe that strong application of contemporary statistical and optimisation techniques and multi stage quality check system helps in developing capability of organisation and assists in enhancing the offshore outsourcing adoption index. Appropriate estimation of project cost also plays critical role in successful adoption of offshore outsourcing because the fluctuation of currency value directly enhances/reduces the estimated project cost within a nation..

Among the four case organisations, organisation 2 achieved highest adoption index (8.404) followed by organisation 3 (8.111), organisation 1 (7.628) and organisation 4 (7.417). From the obtained results, it can be stated that the framework developed has highest adoption of 84 per cent and minimum adoption of 74 per cent during the validation across all the case organisations. The applicability of the developed framework is further strengthened by applying sensitivity analysis. The outcomes of sensitivity analysis show very few changes when the developed framework is tested under different conditions. This portrays that the framework is robust in nature and can be applied to other organisations similar to the selected case organisations. The present research is a novel work carried out in the domain of offshore outsourcing as it presents the unique set of enablers influencing offshore outsourcing adoption. It further utilises a novel combination of BWM-ELECTRE for evaluation of enabler weights and computing each organisations' index scores.

6. Study contributions

This study seeks to provide several noticeable contributions and implications to theory and practices; other details are given in subsequent subsections.

6.1 Theoretical implications

As discussed in literature, several researchers (Kumar, Zampogna, and Nansen 2010; Bardhan, Whitaker, and Mithas 2006; Mehta and Mehta 2017) highlighted the

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enablers/drivers/critical success factors influence the adoption of offshore outsourcing in service sectors but very few studies could link the same to automotive manufacturing sector. Thus, this study contributes to the theory by offering an exhaustive list of enablers to offshore outsourcing in manufacturing context. Various research articles reported in literature discussed the offshore outsourcing enablers based on their occurrence (Mehta and Mehta 2017; Herath and Kishore 2009), however failed to portray the intensity or relative importance of enablers. The identification of relative importance of the enabler is the topmost theoretical contribution made by this work in offshore outsourcing context. The present study is a very initial effort to apply hybrid BWM-ELECTRE approach to evaluate the enablers to facilitate the adoption of offshore outsourcing for the organisations involved in automotive manufacturing environment.

6.2 Implications for practitioners and researchers

This research also offers several implications for researchers and practitioners involved in offshore outsourcing domain are described as follows.

- This is extremely difficult to penetrate all the enablers simultaneously within the organisation. To deal with this, determining the influencing intensity of the enablers is helpful to the industry practitioners in effective offshore outsourcing adoption. In such cases, it is possible that some enablers might highly influence the adoption of offshore outsourcing compared to other enablers. Hence, by identifying the high intensity enablers, the practitioners can focus on the enablers based on their intensities. The provided exhaustive list of offshore outsourcing enablers with their intensities will help the industry practitioners to eradicate the potential issues in effective offshore outsourcing adoption.
- This work provides an in-depth understanding to managers in effective adoption and implementation of offshore outsourcing initiatives by evaluating the adoption index of organisations involved in automotive sector. This research work will be beneficial to both researchers and practitioners from developing economies such as India, China, Brazil, and Thailand, to enhance the success rate of their offshore outsourcing decision initiatives and generate more employment opportunities.
- The hybrid BWM-ELECTRE approach employed in this study possess dual benefits for researchers and practitioners. In the case of handling large number of enablers' with alternatives, ELECTRE provides the most optimal solution. The researchers are

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motivated to enrich its application experience in practicing offshore outsourcing initiatives.

- This study is very helpful when the practitioners are uncertain on intensity of influence of enablers in offshore outsourcing adoption. The conducted sensitivity analysis will assist managers to predict the different working scenario to test the enabler's significance and their level of influence. This will further help policy makers to enhance the adoption index of offshore outsourcing within their organisation. This research work will facilitate managers and professionals involved in practicing offshore outscoring initiatives and results in higher cost advantages on labour and raw material, increased economies of scale, etc.

7. Conclusions, Limitations and Future Scope

This work is an initial attempt to explore the opportunities of offshore outsourcing for organisations involved in automotive sector. The finalised enablers are evaluated by developing an offshore outsourcing decision framework using a hybrid BWM-ELECTRE approach. BWM is utilised to compute the enabler weights whereas ELECTRE is used to evaluate the ranking of automotive case organisations in effective offshore outsourcing adoption. To help practicing managers, this work also uncovers the adoption index score of developed offshore outsourcing decision framework for each case organisation.

Findings of the study reveal that among the main enablers; managerial and strategic enabler holds the highest weight followed by technological enablers and organisational enablers. The framework developed in the present study has highest adoption of 84 per cent and minimum adoption of 74 per cent during the validation across all the case organisations. By enhancing the organisational index score, the automotive manufacturers can attract their clients to increase number of offshore outsourcing projects which will directly enhance the employment rate of skilled professionals. The sensitivity analysis test is conducted to check the robustness of the developed framework. This research work will facilitate managers and professionals involved in practicing offshore outscoring initiatives and results in higher cost advantages on labour and raw material, increased economies of scale, higher sustainable business development etc.

Despite of exhaustive literature review, it is possible that some critical enablers influencing offshore outsourcing adoption might have skipped. More such studies will boost the researchers to explore several other issues of offshore outsourcing. The researchers may

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include the elements of Internet of Things and Industry 4.0 to enhance the offshore outsourcing opportunities for organisations involved in automotive industry domains. The hybrid BWM-ELECTRE approach based developed decision framework employed in this study can further be utilised by researchers to test its applicability across sub-domains of manufacturing (electronics & electrical manufacturing, process manufacturing etc.) based on expert's inputs and industry priorities. This work may provide a strong foundation to offshore outsourcing among related organisations involved in manufacturing in automotive sector.

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Appendix – A

Calculations for the optimal weights using BWM

Calculate the optimal weights ($w_1^*, w_2^*, w_3^*, \ldots w_n^*$): The optimal weight for each criteria generally describes pair of w_B/w_j and $w_j/w_w = a_{jw.}$ In order to fulfil all cases for j, a solution is to be identified for which the maximum absolute difference $|(w_B/w_{j)} - a_{Bj}|$ and $|(w_j/w_{w)} - a_{jw}|$ for all values of j can be minimized. For the case of non-negativity and sum conditions for the weights the above case can be described as:

$$\text{Min } \max_j \{|(w_B/w_{j)} - a_{Bj}|, |(w_j/w_{w)} - a_{jw}|\} \quad \text{Eq. (A.1)}$$

Subject to

$$\sum_j wj = 1$$

$w_j \geq 0$, for all values of j.

Similarly, the same problem can be written as:

Min ξ

Subject to

$$\left|\frac{wB}{wj} - a_{Bj}\right| \leq \xi, \text{ for all values of j} \quad \text{Eq. (A.2)}$$

$$\left|\frac{wj}{ww} - a_{jw}\right| \leq \xi, \text{ for all values of j} \quad \text{Eq. (A.3)}$$

$$\sum_j wj = 1$$

$w_j \geq 0$, for all values of j

By solving the above linear programming problem, the optimal weights are identified.

Further, the consistency index table is provided as:

Table A.1:- Consistency Index table

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a_{BW}	1	2	3	4	5	6	7	8	9
Consistency index (max ξ)	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

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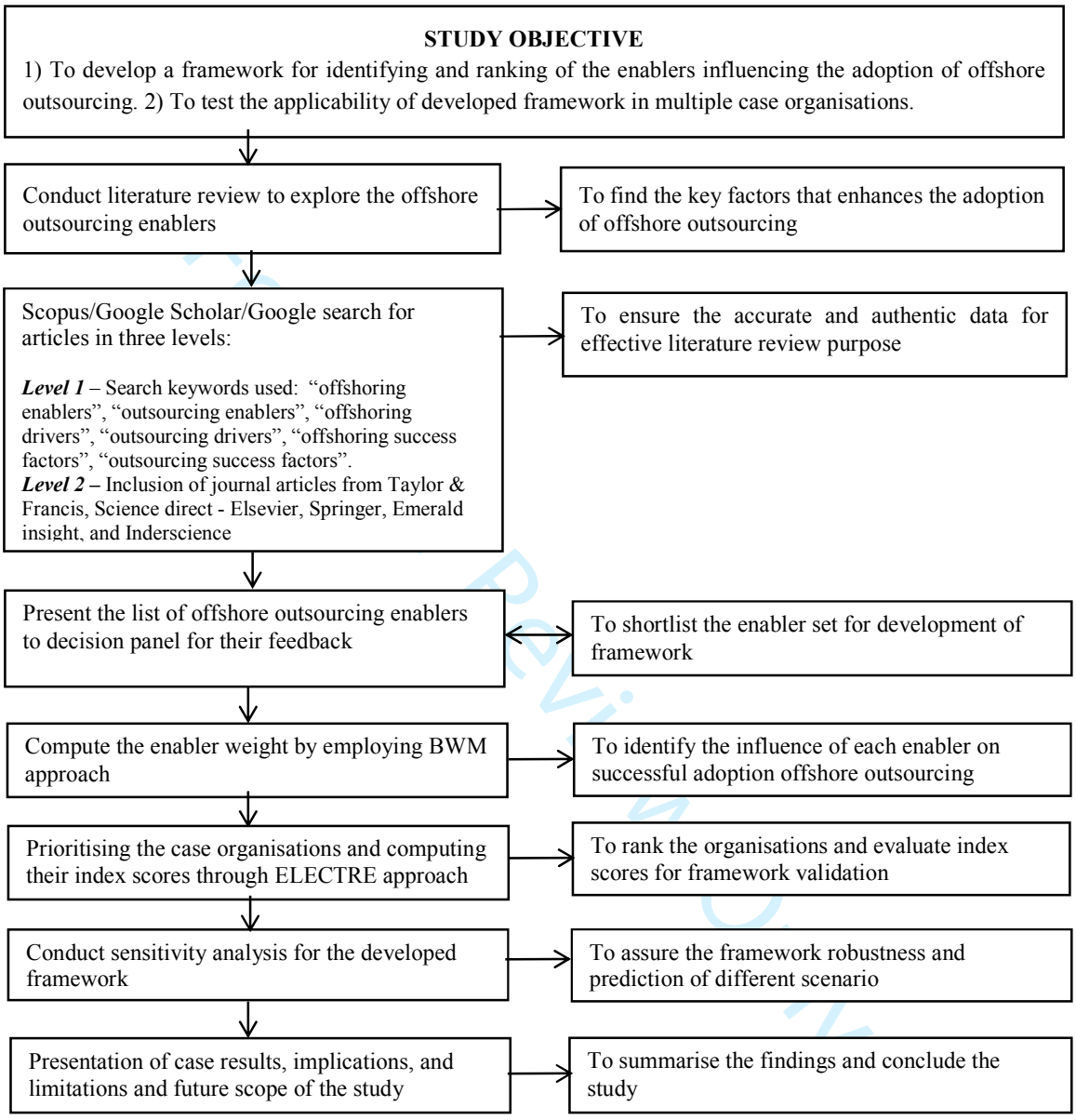

Figure 1:- Research methodology adopted for this study

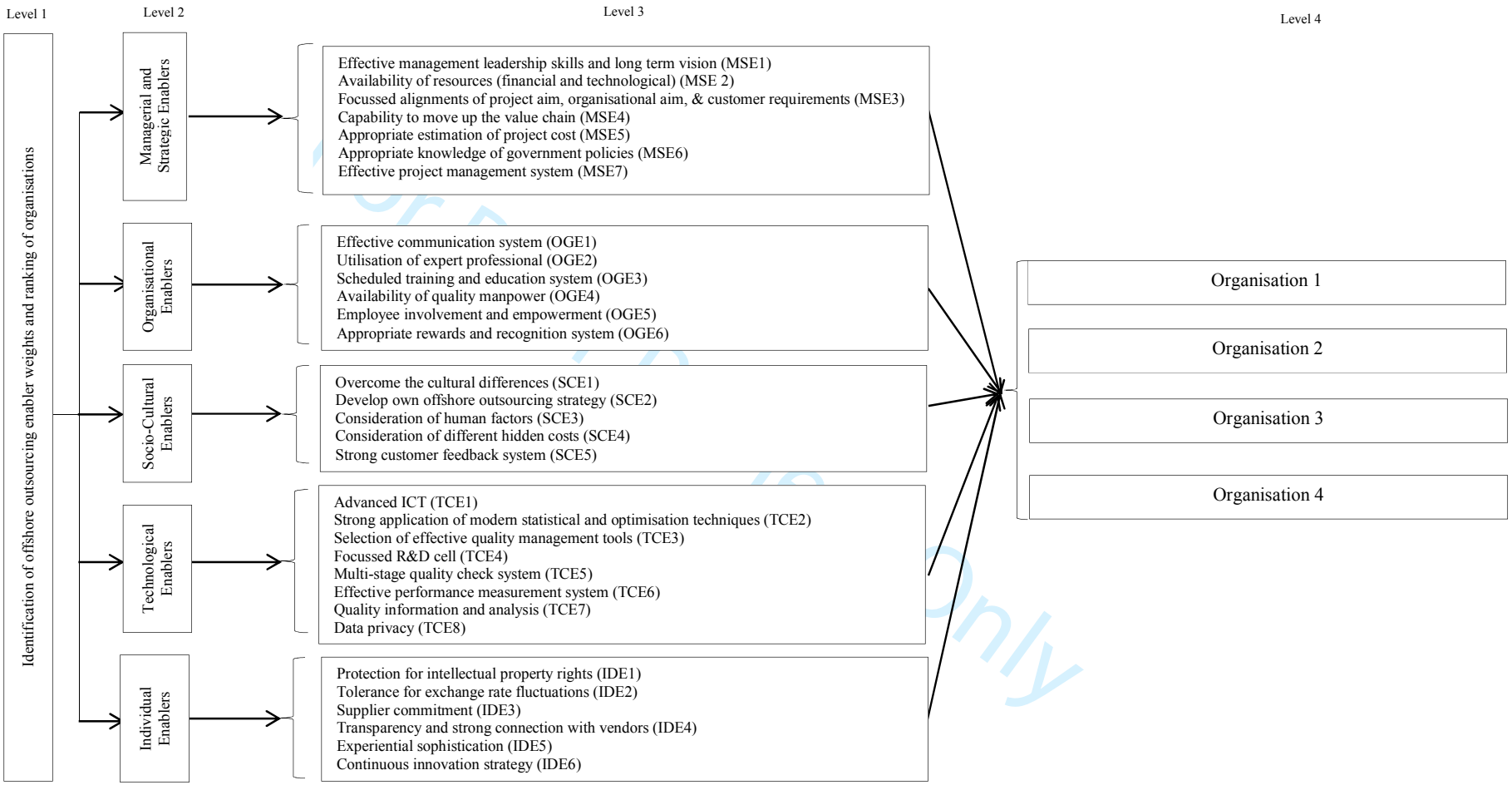

Figure 2:- Developed framework to enhance the adoption of offshore outsourcing

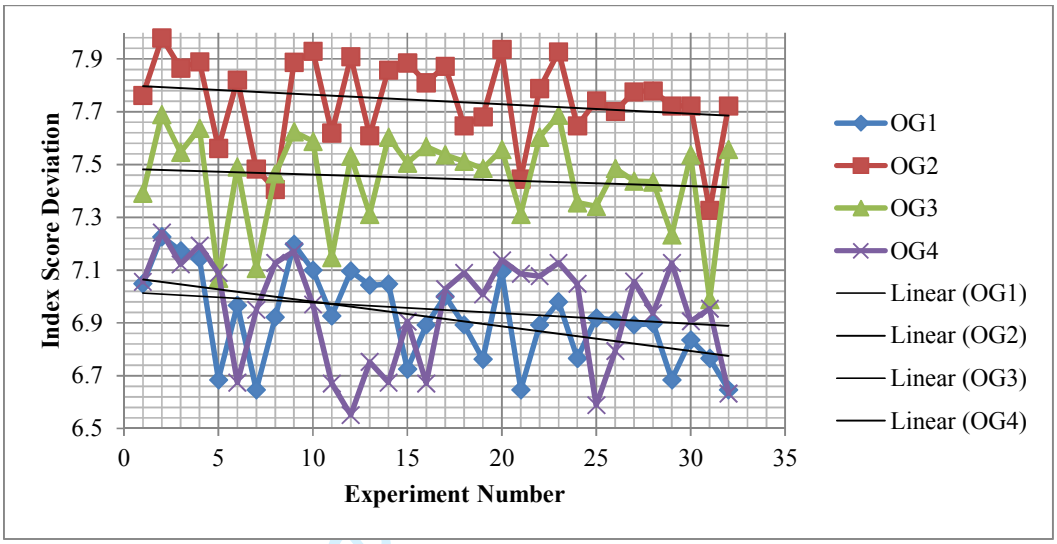

Figure 3:- Sensitivity analysis for condition (A)

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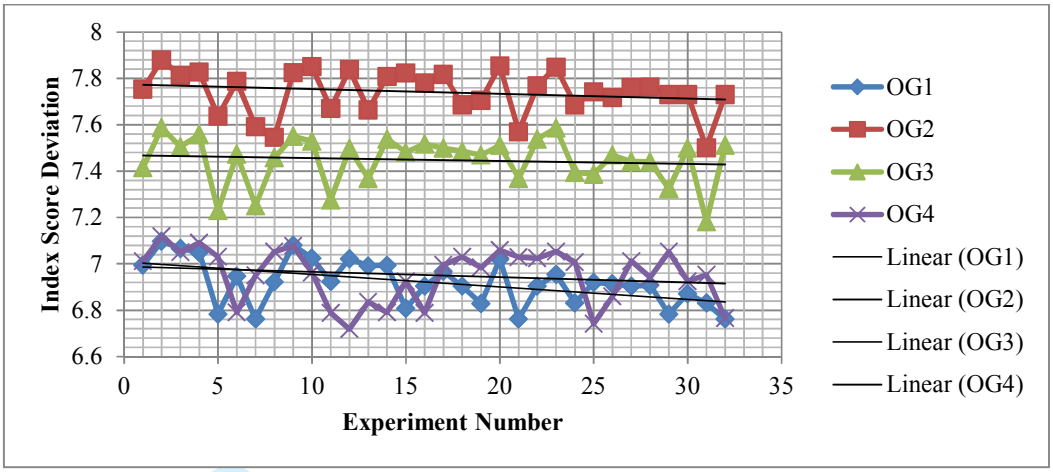

Figure 4:- Sensitivity analysis for condition (B)

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List of Tables

Table 1:- Offshore outsourcing enablers reported in literature

S. No.	Offshore outsourcing enablers	References
1	Effective management leadership skills and long term vision	(Mehta and Mehta 2017; Lahiri and Kedia 2011; Jensen 2012)
2	Availability of resources (financial and technological)	(Herath and Kishore 2009; Kim et al. 2017; Bardhan, Whitaker, and Mithas 2006)
3	Effective communication system	(Mehta and Mehta 2017; Herath and Kishore 2009)
4	Supplier commitment	(Weerakkody and Irani 2010; Gurtu, Searcy, and Jaber 2016)
5	Availability of quality manpower	(Gylling et al. 2015; Wang and Song 2017)
6	Capability to move up the value chain	(Jensen 2012; Lahiri and Kedia 2011)
7	Advanced ICT	(Kumar, Zampogna, and Nansen 2010; Mehta and Mehta 2017; Jensen 2012)
8	Appropriate estimation of project cost	(Herath and Kishore 2009; Kim et al. 2017; Lahiri and Kedia 2011)
9	Effective performance measurement system	(Mehta and Mehta 2017; Kumar, Zampogna, and Nansen 2010)
10	Utilisation of expert professional	(Mukherjee, Gaur, and Datta 2013; Tate et al. 2009)
11	Effective project management	(Quinlan, Hampson, and Gregson 2013; Wang and Song 2017; Weerakkody and Irani 2010)
12	Develop own offshore outsourcing strategy	(Tjader, Shang, and Vargas 2010; Benito et al. 2013)
13	Overcome the cultural differences	(Gurtu, Searcy, and Jaber 2016; Mehta and Mehta 2017)
14	Selection of effective quality management tools	(Benito et al. 2013; Herath and Kishore 2009)
15	Employee involvement and empowerment	(Jensen 2012; Mehta and Mehta 2017)
16	Protection for intellectual property rights	(Lahiri and Kedia 2011; Gurtu, Searcy, and Jaber 2016)
17	Tolerance for exchange rate fluctuations	(Mehta and Mehta 2017; Mella and Pellicelli 2012)
18	Appropriate knowledge of government policies	(Mukherjee, Gaur, and Datta 2013; Tate et al. 2009)
19	Data privacy	(Mella and Pellicelli 2012; Mehta and Mehta 2017)
20	Consideration of different hidden costs	(Kumar, Zampogna, and Nansen 2010; Bardhan, Whitaker, and Mithas 2006)
21	Consideration of human factors	(Mehta and Mehta 2017; Kim et al. 2017)
22	Strong application of modern statistical and optimisation techniques	(Tjader, Shang, and Vargas 2010; Weerakkody and Irani 2010)
23	Focussed alignments of project objectives, organisational aim, and customer requirements	(Tate et al. 2009; Quinlan, Hampson, and Gregson 2013; Gurtu, Searcy, and Jaber 2016)

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24	Transparency and strong connection with vendors	(Gylling et al. 2015; Kim et al. 2017)
25	Continuous innovation strategy	(Jensen 2012; Benito et al. 2013)
26	Scheduled training and education system	(Mehta and Mehta 2017; Lahiri and Kedia 2011)
27	Experiential sophistication	(Gurtu, Searcy, and Jaber 2016; Mehta and Mehta 2017)
28	Focussed R&D cell	(Kumar, Zampogna, and Nansen 2010; Bardhan, Whitaker, and Mithas 2006)
29	Appropriate rewards and recognition system	(Kim et al. 2017; Jensen 2012)
30	Multi-stage quality check system	(Mehta and Mehta 2017; Lahiri and Kedia 2011)
31	Strong customer feedback system	(Kim et al. 2017; Kumar, Zampogna, and Nansen 2010)
32	Quality information and analysis	(Tjader, Shang, and Vargas 2010; Quinlan, Hampson, and Gregson 2013)

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Table 2:- Application of Best Worst Method

Author	Area of Application
(Rezaei 2015b)	Description of Best Worst Method
(Rezaei 2015a)	Description of properties of BWM
(Rezaei, Wang, and Tavasszy 2015)	Linking supplier development to supplier segmentation
(Chitsaz and Azarnivand 2017)	Water Scarcity Management
(Gupta and Barua 2016)	Technological innovation for Indian MSMEs
(Hafezalkotob and Hafezalkotob 2016)	Risk-based material selection process
(Huang and Moh 2016)	Application of Perron Theorem in multi criteria decision making
(Mou, Xu, and Liao 2016)	Fuzzification of BWM
(Ren, Liang, and Chan 2016)	Urban sewage sludge
(Rezaei, Hemmes, and Tavasszy 2016)	Surface transportation of air freight
(Rezaei, Nispeling, et al., 2016)	Supplier Selection
(Salimi and Rezaei 2016)	Measuring efficiency of industry-institute projects

Table 3:- Recent applications of ELECTRE Method

Author	Area of Application
(Mousavi, Gitinavard, and Mousavi 2017)	Renewable energy policy selection
(Kadziński and Ciomek 2016)	Preference Modelling and outranking
(Naghiu et al. 2016)	Solar radiation panel selection
(Wu et al. 2016)	Wind power station site selection
(Ishizaka and Nemery 2014)	Assigning m/c to incomparable maintenance strategies
(Lian and Ke 2014)	Agricultural product recommendation
(Petrović et al. 2014)	EU digital agenda targets

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Table 4:- Case organisations descriptions

	Organisation 1 (OG1)	Organisation 2 (OG2)	Organisation 3 (OG3)	Organisation 4 (OG4)
Product	Passenger Car	Passenger Car	Truck	Truck
offshore and outsourcing initiatives	Gear Box	Gear Box	Suspension	Suspension
Number of employees	79,558	13,259	11,906	6745
Headquarters	Mumbai, India	New Delhi, India	Chennai, India	Kolkata, India
Net income	$4.7 billion	$1.2 billion	$190 million	$ 12 million

Table 5:- Best-to-Others (BO) vectors from 6 experts

Expert No.	Best	MSE	OGE	SCE	TCE	IDE
1	MSE	1	4	6	2	5
2	MSE	1	4	5	4	6
3	MSE	1	5	2	6	4
4	OGE	3	1	6	3	4
5	TCE	3	5	4	1	5
6	SCE	4	2	1	3	4

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Table 6:- Others-to-Worst (OW) vectors from 6 experts

Expert No.	Worst	MSE	OGE	SCE	TCE	IDE
1	SCE	7	3	1	6	3
2	IDE	5	4	2	3	1
3	TCE	6	2	4	1	3
4	SCE	5	6	1	4	2
5	OGE	4	1	2	6	2
6	IDE	2	6	7	4	1

Table 7:- Main enablers weights

Expert No.	MSE	OGE	SCE	TCE	IDE	ξ^L
1	0.439	0.131	0.058	0.263	0.105	0.087
2	0.491	0.155	0.124	0.155	0.071	0.131
3	0.448	0.102	0.256	0.064	0.128	0.064
4	0.181	0.443	0.0568	0.181	0.136	0.102
5	0.192	0.074	0.144	0.473	0.115	0.103
6	0.127	0.255	0.382	0.170	0.063	0.102
Final weights.	0.313	0.193	0.170	0.218	0.103	0.098

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Table 8:- Global weights of offshore outsourcing enablers

Main Criteria	Main Enablers Wt.	Sub Enabler	ξ^L	Local Wt.	Global Wt.
Managerial and Strategic enablers (MSE)	0.313	MSE1	0.119	0.083	0.026
		MSE2		0.321	0.101
		MSE3		0.213	0.067
		MSE4		0.203	0.064
		MSE5		0.045	0.014
		MSE6		0.091	0.029
		MSE7		0.041	0.013
Organisational enablers (OGE)	0.193	OGE1	0.094	0.086	0.017
		OGE2		0.318	0.062
		OGE3		0.255	0.050
		OGE4		0.044	0.009
		OGE5		0.185	0.036
		OGE6		0.109	0.021
Social-Cultural enablers (SCE)	0.170	SCE1	0.073	0.269	0.046
		SCE2		0.207	0.035
		SCE3		0.180	0.031
		SCE4		0.227	0.039
		SCE5		0.115	0.020
Technological enablers (TGE)	0.218	TGE1	0.080	0.079	0.017
		TGE2		0.301	0.066
		TGE3		0.083	0.018
		TGE4		0.165	0.036
		TGE5		0.211	0.046
		TGE6		0.069	0.015
		TGE7		0.036	0.008
		TGE8		0.054	0.012
Individual enablers (IDE)	0.103	IDE1	0.053	0.242	0.025
		IDE2		0.177	0.018
		IDE3		0.157	0.016
		IDE4		0.180	0.019
		IDE5		0.087	0.009
		IDE6		0.153	0.016

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Table 9:- Initial comparison of matrix for ELECTRE

Main Criteria	Sub-Criteria	OG1	OG2	OG3	OG4
Managerial and Strategic enablers (MSE)	MSE1	7.972	7.916	6.985	7.812
	MSE2	9.425	9.688	9.417	9.333
	MSE3	8.983	8.755	8.25	8.349
	MSE4	8.75	8.955	8.989	8.933
	MSE5	5	6.277	4.361	8.083
	MSE6	7.305	8.388	7.8	4.694
	MSE7	4.694	5.638	4.667	6.944
Organisational enablers (OGE)	OGE1	6.944	5	7.583	8.389
	OGE2	9.188	8.933	8.883	8.75
	OGE3	8.388	9.283	8.589	7.111
	OGE4	6.977	6.75	5	4.667
	OGE5	8.361	9.111	8.128	3.694
	OGE6	7.922	6.667	6.333	5.333
Social-Cultural enablers (SCE)	SCE1	7.961	8.694	8.722	4.694
	SCE2	5.333	8.917	7.922	6.583
	SCE3	6.694	8.306	8.465	4.667
	SCE4	7.583	8.817	8.167	7.583
	SCE5	6.694	6.972	7.972	8.083
Technological enablers (TGE)	TGE1	5.638	7.25	7.75	7.417
	TGE2	8.348	9.333	8.333	8.478
	TGE3	4.694	5.333	6.333	8.056
	TGE4	6.694	8.127	8.722	7.983
	TGE5	7.416	9.261	9.394	8.394
	TGE6	5.666	6.972	6.694	7.75
	TGE7	6.916	7.75	6.583	4
	TGE8	6.838	7.417	7.75	5.667
Individual enablers (IDE)	IDE1	6.694	8.028	7.361	7.817
	IDE2	6.744	8.056	7.333	6.839
	IDE3	5	7.583	5.694	8.389
	IDE4	6.238	7.583	8.167	6.588
	IDE5	5.666	4.361	3.694	6.978
	IDE6	4.694	7.583	8.333	4.361

Table 10:- Final ranking of organisations

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Organisation	Concordance Credibility	Discordance Credibility	Superiority Ratio	Rank
OG1	2.306	3.2246	0.715127458	3
OG2	3.7837	1.617	2.339950526	1
OG3	3.2846	3.1957	1.027818631	2
OG4	2.1845	3.5215	0.620332245	4

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Table 11:- Initial comparison of matrix for ELECTRE

Sub-Criteria	Weights	OG1	OG2	OG3	OG4
MSE1	0.026	0.208	0.207	0.182	0.204
MSE2	0.101	0.950	0.977	0.949	0.941
MSE3	0.067	0.601	0.586	0.552	0.558
MSE4	0.064	0.557	0.570	0.572	0.569
MSE5	0.014	0.071	0.089	0.062	0.114
MSE6	0.029	0.209	0.240	0.223	0.134
MSE7	0.013	0.061	0.074	0.061	0.091
OGE1	0.017	0.115	0.083	0.126	0.139
OGE2	0.062	0.566	0.551	0.548	0.539
OGE3	0.050	0.416	0.460	0.426	0.352
OGE4	0.009	0.060	0.058	0.043	0.040
OGE5	0.036	0.299	0.326	0.291	0.132
OGE6	0.021	0.168	0.141	0.134	0.113
SCE1	0.046	0.366	0.400	0.401	0.216
SCE2	0.035	0.188	0.315	0.280	0.232
SCE3	0.031	0.205	0.255	0.259	0.143
SCE4	0.039	0.293	0.341	0.316	0.293
SCE5	0.020	0.131	0.137	0.157	0.159
TGE1	0.017	0.097	0.125	0.133	0.128
TGE2	0.066	0.548	0.613	0.547	0.557
TGE3	0.018	0.085	0.097	0.115	0.146
TGE4	0.036	0.241	0.293	0.314	0.288
TGE5	0.046	0.341	0.426	0.433	0.386
TGE6	0.015	0.085	0.105	0.101	0.117
TGE7	0.008	0.054	0.061	0.051	0.031
TGE8	0.012	0.080	0.087	0.091	0.067
IDE1	0.025	0.168	0.201	0.184	0.196
IDE2	0.018	0.124	0.148	0.135	0.126
IDE3	0.016	0.081	0.123	0.092	0.136
IDE4	0.019	0.116	0.141	0.152	0.122
IDE5	0.009	0.051	0.039	0.033	0.063
IDE6	0.016	0.074	0.120	0.132	0.069
Adoption Index Score		**7.628**	**8.404**	**8.111**	**7.417**

Table 12:- Experiment details of sensitivity analysis

Exp. No.	(A) At fixed wt.= 0.15 variable wt. = 0.0290				(B) At fixed wt.= 0.1 variable wt. = 0.0274			
	OG1	OG2	OG3	OG4	OG1	OG2	OG3	OG4
1	7.048	7.762	7.391	7.056	6.994	7.753	7.415	7.011
2	7.226	7.979	7.689	7.242	7.097	7.879	7.587	7.119
3	7.172	7.865	7.546	7.122	7.066	7.812	7.504	7.049
4	7.144	7.889	7.636	7.193	7.049	7.827	7.557	7.091
5	6.684	7.561	7.069	7.089	6.783	7.637	7.228	7.031
6	6.967	7.820	7.491	6.674	6.947	7.786	7.473	6.790
7	6.647	7.483	7.107	6.949	6.761	7.591	7.250	6.950
8	6.922	7.404	7.464	7.126	6.921	7.546	7.457	7.052
9	7.197	7.887	7.623	7.171	7.080	7.825	7.549	7.078
10	7.099	7.930	7.587	6.970	7.023	7.850	7.529	6.962
11	6.926	7.619	7.147	6.670	6.923	7.670	7.274	6.788
12	7.096	7.908	7.531	6.551	7.022	7.838	7.496	6.719
13	7.042	7.609	7.311	6.752	6.990	7.664	7.368	6.835
14	7.047	7.857	7.604	6.674	6.993	7.808	7.538	6.790
15	6.725	7.88	7.506	6.905	6.807	7.824	7.481	6.924
16	6.892	7.810	7.567	6.670	6.903	7.781	7.517	6.788
17	7.001	7.872	7.536	7.028	6.966	7.817	7.499	6.995
18	6.892	7.646	7.512	7.089	6.903	7.686	7.485	7.031
19	6.762	7.680	7.485	7.007	6.828	7.706	7.469	6.983
20	7.094	7.936	7.556	7.137	7.021	7.853	7.510	7.059
21	6.647	7.445	7.311	7.086	6.761	7.570	7.368	7.029
22	6.892	7.788	7.604	7.077	6.903	7.768	7.538	7.023
23	6.980	7.927	7.686	7.127	6.955	7.848	7.586	7.053
24	6.766	7.646	7.355	7.048	6.830	7.686	7.394	7.007
25	6.919	7.742	7.342	6.588	6.919	7.741	7.386	6.741
26	6.909	7.701	7.485	6.793	6.914	7.717	7.469	6.859
27	6.892	7.776	7.437	7.056	6.903	7.761	7.441	7.012
28	6.898	7.779	7.433	6.936	6.907	7.763	7.439	6.942
29	6.684	7.721	7.233	7.126	6.783	7.729	7.323	7.052
30	6.836	7.721	7.536	6.906	6.871	7.729	7.499	6.924
31	6.766	7.326	6.987	6.953	6.830	7.501	7.181	6.952
32	6.647	7.721	7.556	6.633	6.761	7.729	7.510	6.766

Appendix – A

Calculations for the optimal weights using BWM

Calculate the optimal weights (w_1^*, w_2^*, w_3^*,…. w_n^*): The optimal weight for each criteria generally describes pair of w_B/w_j and $w_j/w_w = a_{jw.}$ In order to fulfil all cases for j, a solution is to be identified for which the maximum absolute difference $|(w_B/w_{j)} - a_{Bj}|$ and $|(w_j/w_{w)} - a_{jw}|$ for all values of j can be minimized. For the case of non-negativity and sum conditions for the weights the above case can be described as:

$$\text{Min max}_j \{|(w_B/w_{j)} - a_{Bj}|, |(w_j/w_{w)} - a_{jw}|\} \quad \text{Eq. (A.1)}$$

Subject to

$$\sum_j wj = 1$$

$w_j \geq 0$, for all values of j.

Similarly, the same problem can be written as:

Min ξ

Subject to

$$\left|\frac{wB}{wj} - a_{Bj}\right| \leq \xi, \text{ for all values of j} \quad \text{Eq. (A.2)}$$

$$\left|\frac{wj}{ww} - a_{jw}\right| \leq \xi, \text{ for all values of j} \quad \text{Eq. (A.3)}$$

$$\sum_j wj = 1$$

$w_j \geq 0$, for all values of j

By solving the above linear programming problem, the optimal weights are identified.

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Further, the consistency index table is provided as:

Table A.1:- Consistency Index table

a_{BW}	1	2	3	4	5	6	7	8	9
Consistency index (max ξ)	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

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